Weather and Climate Extremes 3 (2014) 54–61

Contents lists available at ScienceDirect

Weather and Climate Extremes

journal homepage: www.elsevier.com/locate/wace

# Vulnerability and policy relevance to drought in the semi-arid tropics of Asia – *A retrospective analysis*

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ARTICLE INFO

*Article history:*
Received 25 November 2013
Accepted 13 February 2014
Available online 25 February 2014

*Keywords:*
Drought
Vulnerability
Impact assessment
Semi-arid tropics

ABSTRACT

Of all the natural hazards, drought affects the maximum number of people globally causing devastating impacts. It is a reality that drought results in sets of socio-economic impacts starting with crop-yield failure, unemployment, erosion of assets, income decrease, poor nutrition and decreasing risk absorptive capacity, thereby increasing the vulnerability of the community. This paper gives a brief of the existing approaches that focus on vulnerability and impact assessment aid to characterize and identify regions, sectors and communities which are at risk for drought currently and in the future. It also discusses the limitation, constraints and pre-requisites in these approaches and highlights the importance of micro-level information to have a more realistic understanding of impact and vulnerability through illustration, with reference to the recent study conducted by the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). This exercise will provide a guiding framework for devising action plans to improve adaptive capacity among vulnerable populations.



## 1. Introduction

The relevance of climate extreme events such as droughts and its impacts is well recognized. Climate change modeling studies have shown that the tropics of Asia and Africa could experience a significant change in the frequency of occurrence and the intensity of droughts (IPCC, 2007). Droughts have a multidimensional effect on humanity in terms of several socio-economic parameters like agriculture, human health, sea level rise, scarcity of labor, disease prevalence, etc. (Adger, 1999). Droughts are expected to impact livelihood and their occurrence will further aggravate poverty levels and sustainability of livelihood means in the years to come. The adversities resulting from droughts emphasize the importance of strategies needed to cope with the impacts. Unless well-thought strategies are implemented, they can result in a far reaching consequence and cause severe impacts on societies and livelihood especially among the natural resource dependent communities (Tompkins and Adger, 2004; Thomas and Twyman, 2005). Managing vulnerability and enhancing resilience against drought are the major pressing issues particularly among the developing tropical countries of the continent. However, the impacts, vulnerability and capacity to adapt to these changes differ with time and space. For the same reason, international and national organizations, viz., United Nations Framework Convention on Climate Change (UNFCCC), World Meteorological Organization (WMO), United Nations Convention to Combat Desertification (UNCCD), etc., are partnered to formalize plans to minimize the impact. Understanding the concept of vulnerability, its extent, mapping, formulating vulnerability functions enabling drought risk impact assessments, and the gravity of its dynamics at the levels of significance are needed before drought management planning can be put into action (O'Brien et al., 2004). These exercises will aid in recognizing, prioritizing, planning and channeling the resources to improve the capacity to adapt. Furthermore, the existing constraints in financing the adaptation apply equally to all regions. So prioritizing the regions needs special attention and one should take into account the vulnerabilities and impacts caused by climate change.

## 2. Background and quantifying framework

Various definitions on climate related 'vulnerability' exist among others that are usually associated with natural hazards like floods, droughts, and socio hazards like poverty. The Intergovernmental Panel on climate change (IPCC) has defined vulnerability as the degree to which a system is susceptible to or unable to cope with the adverse effects of climate change, including climate variability and extremes. With the increased importance of climate change research, it has been widely used to compute vulnerability. Vulnerability analysis is a

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http://dx.doi.org/10.1016/j.wace.2014.02.002

unique art of science and an attempt to quantify and map vulnerability to climate change for the entity or target region. In climate change research, vulnerability has three components: exposure, sensitivity and adaptive capacity. (i) Exposure can be interpreted as the direct danger (i.e., the stressor) and the nature and extent of changes to a region's climate variables (e.g. temperature, precipitation, and extreme weather events). (ii) Sensitivity describes the human-environmental conditions that can worsen the hazard, ameliorate the hazard, or trigger an impact. (iii) Adaptive capacity represents the potential to implement adaptation measures that help to avert potential impacts (Adger et al., 2005; Vincent, 2007).

Drought impact assessment studies the consequence of drought, and identifies the sectors/sections having direct impacts, such as reduced crop yields, livestock losses, depleting natural resources vis-a-vis water reservoir depletion, etc., and links them to secondary effects such as income loss, unemployment, forced migration or famine (ESCWA, 2006). The drought will result in a set of unique impacts, depending not only on its severity and duration, but also on a society's social, economic and environmental conditions. To realize drought vulnerability and understand the impacts at different levels, i.e., the macro- (region/country), meso- (state/district/country) and micro-levels (village/communities, etc.), exploring the knowledge or information of these regions and the direct and indirect consequences that contribute to vulnerability, and analyzing regional and attained capacity to cope are necessary. Drought vulnerability and impact research should examine how the impacts of drought are the result of the interactions of agro-socio-economic factors with the meteorological drought phenomenon (Bantilan and Keatinge, 2007). The vulnerability of communities to drought is dependent on hosts of physical, social, environmental and economic characteristics (Molua and Lambi, 2007). Furthermore, regions that are socio-economically underdeveloped are more severely affected by the effects of climate change than others, especially in an economy closely tied to its natural-resource base and climate-sensitive sectors such as agriculture, water, forestry, etc. From these studies, it has almost been proved that vulnerability is closely associated with poverty, as the poor are least capable of responding to these extreme climatic stimuli. Globally, several studies on indexing regions based on climate vulnerability have been carried out especially in Asia and Africa where a large chunk of the rural poor and agriculturally dependent population still lives (Nhemachena et al., 2008; Hoddinott and Quisumbing, 2008). Studies in profiling vulnerable regions have been done for regions in India: SAT India (Singh et al., 2013), North east India (Ravindranath et al., 2011) and the lower Himalayas (Pandey and Jha, 2012). The majority of the vulnerable population of semi-arid tropics is poorly equipped to cope effectively with the adversities of climate change due to low capabilities, weak institutional mechanisms, and lack of access to adequate resources (Bantilan and Anupama, 2006; Jodha, 2005; Ribot, 2001). The purpose of the paper is to highlight the approaches in assessing drought vulnerability and the policy relevance particularly in the semi-arid tropics of India.

## 3. Assessing drought vulnerability and impacts

There are broad three approaches present and widely used in assessing vulnerability and impacts namely (a) socio-economic approach, (b) biophysical approach and (c) integrated approach that adopts a mix of both the socio-economic and biophysical indicators. The socio-economic approach is largely pertaining to the social, economic, and political aspects of society and it focuses on the assessment of the socio-economic and political status of individuals or social groups (Adger, 2000). The biophysical approach is mainly concerned with the physical impacts of climate change on different attributes, such as yield and income (Fussel and Klein, 2006; Fussel, 2007). The integrated assessment approach combines both the socio-economic and the biophysical attributes in vulnerability analysis (Fussel, 2007). In this approach the vulnerability analysis conceptualizes vulnerability as a function of adaptive capacity, sensitivity, and exposure to events such as drought (Brooks et al., 2005). The risk-hazard framework (biophysical approach) corresponds most closely to sensitivity in the IPCC concept and terminology. Adaptive capacity is largely consistent with the socio-economic approach. In the IPCC framework, exposure has an external dimension, whereas both sensitivity and adaptive capacity have an internal dimension, which is implicitly assumed in the integrated vulnerability assessment framework. Mapping of the region and population that are at risk due to climate change through the IPCC method (Iyengar and Sudarshan, 1982) with components of exposure, sensitivity and adaptive capacity is generally carried out. For example, a case study on mapping the districts of Andhra Pradesh and Maharashtra based on socio-economic vulnerability to climate change in the semi-arid tropics of India (Fig. 1) was carried out using a similar methodology.

These approaches have their merits and limitations. The main limitations of the socio-economic approach are that it focuses only on the variations within society or social groups, and overlooks the environment-based intensities, frequencies, and probabilities of environmental shocks, such as drought and flood (Yohe and Tol, 2002; Deressa et al., 2009). The biophysical approach is similar to the risk-hazard approach and the major limitation of this is that it focuses on the physical damage due to climate change variables. Even though the integrated assessment approach corrects the weaknesses of the other approaches, it also has its limitations. There is no standard method for combining the biophysical and socio-economic indicators. The relative importance of different variables used in this approach has not been taken into account and thus more care is needed in using this approach. The other drawbacks are that it does not take into account the dynamism in vulnerability.

## 4. Scoping drought research in the semi-arid tropics through village level studies

The farmers' adaptation measures should be looked at continuously, and learning should be complemented by the experience gained from the micro-level (households/village/community). Expectations are largely linked to micro-level experiences. Here it can be used to build a repository on opportunities and constraints that farmers are currently facing. The problems faced by the farmers are numerous and it is imperative to track these changes to quantify the level of vulnerability. In Jodha et al.'s (2012) paper, a comprehensive description of 'why micro-level information is important in adaptation planning' and the way to create an enabling environment to improve the capacity to adapt for the farmer is provided (Fig. 2).

Its situation varies widely with the cultural, socio-economic and agricultural setup of the village. Villages have a long historical perspective on how they evolved over the years and an experience of events as perceived by the farmers. Hence, it is important that each village should be considered as a unit of analysis and a deeper understanding will definitely aid in creating a sufficient information base of these villages and regions (Aggarwal et al., 2010). The agricultural enterprise, farm and non-farm related sources of income, and the access to different assets of the village households are largely dependent on the natural-environmental setup of the village. The short and long term measures, as well as the individual and collective coping measures against risks, form a part of the overall adaptation strategies of dry land farmers. The adaptation/adjustment to extremes in the short and long term contexts, as manifested by the different features of farming systems in the arid and semi-arid

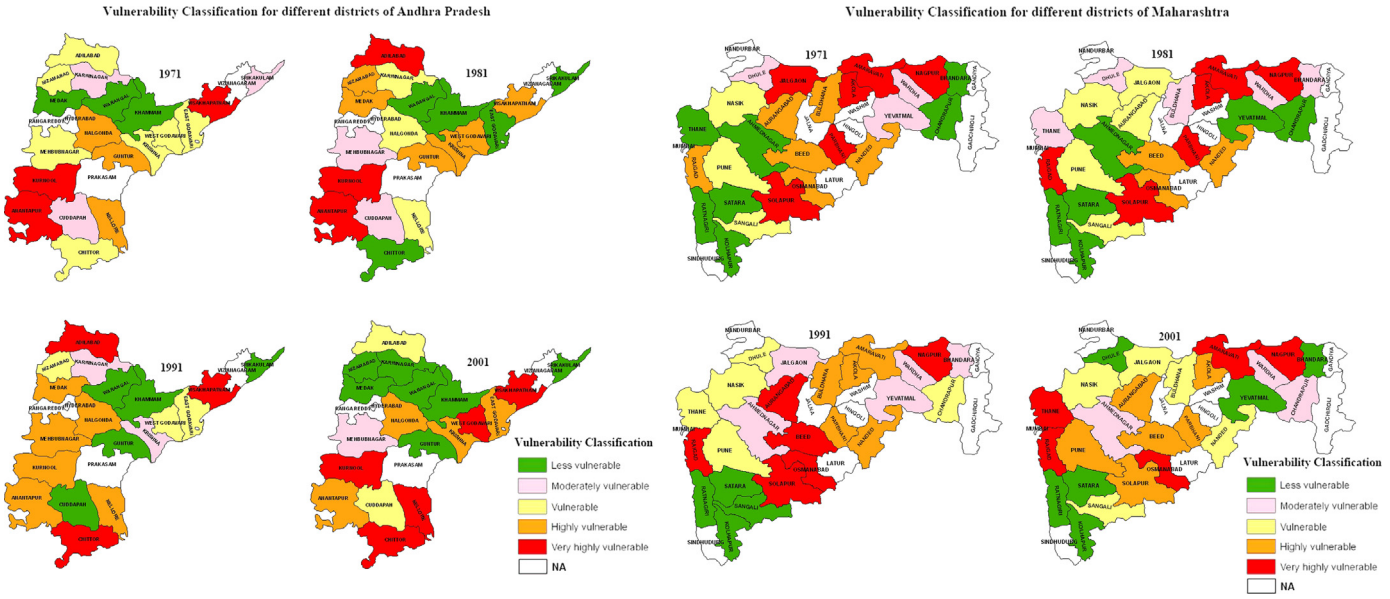


**Fig. 1.** Climate change vulnerability district maps for the states of Andhra Pradesh and Maharashtra, India (Singh et al., 2013). Mapping was done as a part of the project "Vulnerability to Climate Change: Adaptation Strategies and layers of resilience" implemented by the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT).

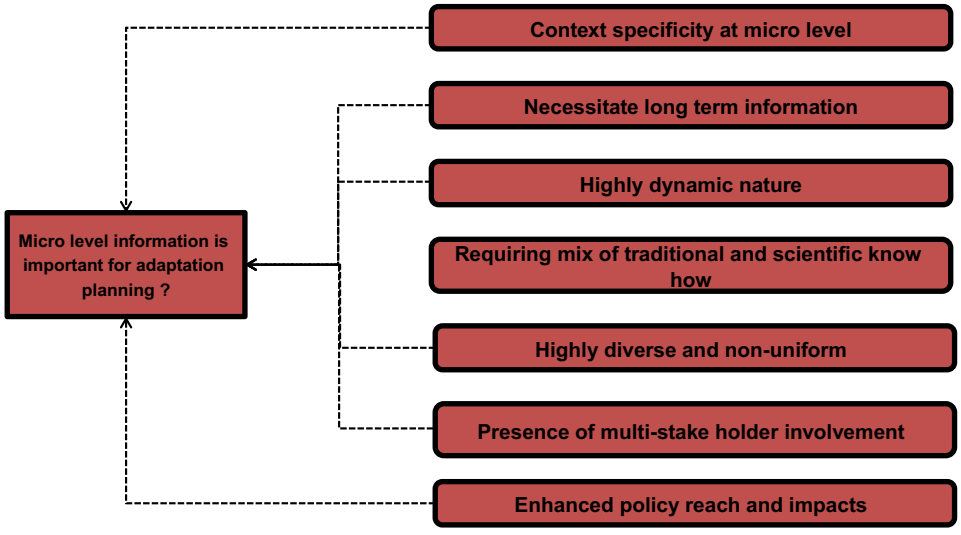


**Fig. 2.** Illustration on the importance of micro-level information in adaptation processes and planning (adapted from Jodha et al., 2012).

regions, briefly alludes to an earlier one. Based on the intra-regional biophysical and socio-economic differences, the adaptations show considerable diversity and flexibility as well as a gradual change in their contents with the changing constraints and opportunities. The scope for enhancing the traditional adaptations by incorporating new elements considering the highly dynamic nature of household behavior and decision making is considered. An important implication of this possibility is to make the new development components for dry regions more resilient. Resilience to risks and different orders of impact results from the risk on the rural economy of the village. Understanding the micro-level strategies and its determinants is a mix of knowledge which needs help in harmonizing the traditional adaptations and the new ones, based on the use of modern science and technologies as well as varied insights and understanding generated by research. Farmers' adaptations are characterized by a high extent of diversity and flexibility as required by spatial and temporal variations affecting the farmers' responses (Walker and Ryan, 1990; VDSA, 2013). With the availability of several present-day technological and management related options, the diversity and flexibility aspects can be addressed if the decision makers and planners are conscious of such possibilities. Recognizing the merits of a multitude of programs, implemented by various government organizations, these interventions must be coordinated to ensure better targeting and efficiency. Finally, we are aware that the vulnerability of locations and farmers varies widely. Therefore, the vulnerability level must be assessed, prioritized and the program channeled accordingly. Ultimately, definite policy reach and impacts aim to move forward the livelihood of the poor from less to more sustainable (Turner et al., 2003; Kurukulasuriya and Mendelsohn, 2008; Stringer et al., 2009). We expect that these continuous monitoring and research initiatives could answer their concerns. Key findings and policy recommendations having direct implications on the ongoing debate and the acceptance of adaptation strategies at the grassroots level are important for discussion during national policy formulations.

### 4.1. How farmers perceive the trends in climate changes

From the analysis of farmers' perception on climate related risks conducted in the study in the villages of the Andhra Pradesh

**Table 1**
Farmers' perception on changes in climatic factors [a].

| Climatic parameters | Kanzara (Akola district, Maharashtra) | | | |
|---|---|---|---|---|
| | 1970–1990 | % of respondents | 1990–2008 | % of respondents |
| Amount of rainfall | Decreased | 73 | Highly decreased | 100 |
| Intensity of rainy days | Decreased | 57 | Decreased | 100 |
| Arrival of monsoon | On time | 97 | Delayed | 100 |
| Distribution of rainfall | Less erratic | 92 | Erratic | 100 |
| Temperature | Increased | 53 | Increased | 100 |
| Occurrence of droughts | Increased | 57 | Highly increased | 83 |
| | **Shirapur village (Solapur district, Maharashtra)** | | | |
| Amount of rainfall | Increased | 97 | Decreased | 100 |
| Intensity of rainy days | Increased | 97 | Decreased | 100 |
| Arrival of monsoon | On time | 100 | Delayed | 100 |
| Distribution of rainfall | Less erratic | 100 | Erratic | 100 |
| Temperature | No change | 77 | Increased | 87 |
| Occurrence of droughts | Increased | 67 | Increased | 73 |
| | **Dokur village (Mahabubnagar district, Andhra Pradesh)** | | | |
| Amount of rainfall | Increased | 100 | Highly decreased | 100 |
| Intensity of rainy days | Increased | 93 | Highly decreased | 100 |
| Arrival of monsoon | On time | 52 | Delayed | 100 |
| Distribution of rainfall | Less erratic | 100 | Erratic | 100 |
| Temperature | No change | 67 | Increased | 100 |
| Occurrence of droughts | Increased | 70 | Highly increased | 87 |

[a] % of the respondents ($n=30$ for each village); ICRISAT (2012).

and Maharashtra states of India, it was revealed that a majority of farmers perceived a reduction in the amount of rainfall over the years and the sampled farmers unanimously agreed to the fact that there is continuous delayed arrival of monsoon and an increased erraticism in the distribution of rainfall in the recent decades (Table 1). Increased delayed arrival and erraticism of rainfall had exerted pressure on their farming decisions that heavily influenced crop planning, income sources, and other alternatives. Changes in the annual rainy days and rainfall quantum with minimum assurance of average rainfall are major concerns among villagers. Atmospheric temperature has increased significantly over the years and farmers feel that they experienced extreme temperatures during summer months. During the summer months due to acute water shortage, farming is not taken up. The rural population agreed unanimously that unpredictable weather perils often disturb the village economy and are considered to be an important factor affecting socio-economic stability and sustainability (Cooper et al., 2008). An increase in the atmospheric temperature will have an impact on crop yield by reducing productivity and inducing water stress. The intra-seasonal drought coincides with the crop's critical growth resulting in a low yield. Crop stresses could be multi-factorial with moisture stress, pest and diseases together with input constraints which reflect on crop yield. These climatic abnormalities could result in crop losses and eventually in debt/loans. Among climatic stresses, moisture stress faced by farmers is considered predominant. Analyzing the percentage of sample households and responding to the climatic trend, the acuteness of the perception of climatic distress was experienced by farmers of resource poor villages (Bunce et al., 2010; Banerjee et al., 2012).

### 4.2. Farmers' perception on Impacts on rural livelihood of Andhra Pradesh

Cereals especially rice used to be the major crop in these SAT villages in Andhra Pradesh. The rising demand for irrigation and perpetual drought resulted in a change in cropping pattern from cereals to drought tolerant (e.g. castor) or short duration crops (e.g. soybean). Switching from cereals (coarse and fine) to pulses and oilseed (having relatively less water requirement) and significant reduction in the area in the later phase of analysis were evident. Multiple cropping with minimum addition of soil emoluments, viz., organic manure, etc., has degraded the soil and there has been an increased use of crop inputs (Table 2). Moreover, adoption of better performing improved varieties during the last three decades also significantly increased the input use. This diminishing soil fertility, increased application of inorganic fertilizers, and decreased micronutrient and input use efficiency of the soil that ultimately raised the cost of cultivation are features that are common in these villages. The perception on the trends in quality, accessibility and availability of common property resources (CPRs) to the community has diminished widely with over-exploitation, improper management and population pressure. Population pressure triggered conversion of more land into cultivation and fragmentation of holdings. With decreased irrigation options, fallow land increased significantly and cultivation that is highly dependent on the unreliable monsoon diminished. Increased crop failure, fluctuations in produce price and lack of supplementary sources for irrigation forced farmers to skip cultivation by abandoning land, which was visible in these villages. All these impacts as perceived differ significantly among the study villages and the perceptions are at the higher end in resource poor villages than the better resource endowed villages.

**Table 2**
Farmers' perception on impacts of climate change on rural livelihood.

| Factors [a] | Kanzara | Shirapur | Dokur | $\chi^2$ |
|---|---|---|---|---|
| Increased occurrence of consecutive drought | 37 | 57 | 100 | 0.00[b] |
| Reduction in gross cropped area | 0 | 0 | 100 | 0.00[b] |
| Reduction in irrigated area | 0 | 0 | 100 | 0.00[b] |
| Reduction in proportion of area under cereal cultivation | 13 | 0 | 57 | 0.00[b] |
| Reduction in availability of alternative water source | 20 | 0 | 93 | 0.00[b] |
| Reduction in land/soil fertility | 47 | 97 | 97 | 0.00[b] |
| Reduction in crop yield | 0 | 0 | 12 | 0.04[b] |
| Increase in inputs (irrigation, fertilizer, etc.) | 13 | 17 | 100 | 0.01[b] |
| Decrease in accessible common property resources | 0 | 37 | 67 | 0.00[b] |
| Reduction in bio-diversity | 37 | 67 | 93 | 0.00[b] |

[a] % of the respondents ($n=30$ for each village).
[b] Significant at 5% level; the chi-square test relates to significance of differences between three villages vis-à-vis perceptions; ICRISAT (2012).

This implies that the condition of villages significantly influences the farmers' perceptions on the impacts and climate related risks.

Identification of vulnerable regions through socio-economic indicators and understanding household level linkages to poverty are the next steps. Household linkages at vulnerable regions need to be explored to understand how farmers perceived these changes of cropping patterns, income levels, output and input markets, diversification, etc. A household level survey and analysis gave a clear picture of what has been happening in terms of adaptation strategies to climate change. It is clear that the study countries in Asia are heterogeneous and the impact of climate change will vary from one location to the other depending on various climatic conditions, as well as environmental and contextual factors (ICRISAT, 2012). The latter will include historical, social, economic conditions and governance status faced by the people and the institutional framework within which they function (Agrawal, 2008). People's sense of reality is acquired strength that is gained through life experiences, learning, wealth and one's own perceptions and values that will to a great extent provide the impetus to act. In the context of climate responsiveness, the values and perceptions that define their actions are of paramount importance to understand their adaptive behavior.

## 5. Drought policy relevance in SAT region

Ensuring sufficient food for the ever-increasing global population through improved productivity and increased resource use and efficiency continues to be a key challenge in this century. Since the competition for natural resources like water and land is increasing, compounded by the challenge of climate and the associated variability of weather and its impact on agriculture, the challenge appears to be even more daunting (Shiferaw et al., 2009). The global community must produce more using diminishing natural resources under uncertain climate conditions in agriculture. Agricultural production systems are also to be environmentally friendly by reducing carbon emissions. Indeed this is a daunting task. To achieve this task of paving the way for a "climate smart agriculture", several measures must be taken that include enabling policies, institutions and infrastructure, and farm communities being better informed and empowered with necessary resources. However, these strategies and plans are not properly oriented to cater to specific regional or local needs. These programs may be implemented with a downstream approach to have maximum response where the targeted stakeholders receive maximum benefits. The following policy recommendations are the outcomes of the grassroots level work and the macro-climate data analysis. They are also based on the perceptions and expectations of the stakeholders, especially the farmers, the ultimate beneficiary of SAT India (Table 3).

### 5.1. Enabling environment

The ability of farmers, community based organizations and local agencies to act effectively and in the interest of the local residents depends very much on the "space" created for such work. With increasing writ of the state being asserted in the periphery, most services will be delivered by the state minimizing the scope for local engagement. However, the state can also benevolently legislate the local involvement or participation. Given the diversity and complexity of local situations, it is not practical or feasible to obtain total understanding of local situations. State planning cannot be done effectively from the center with minimum engagement of the periphery or the local communities or their representatives. The state should provide effective capacity development, resourcing and instituting a process that enables local participation to improve the validity and relevance of externally facilitated processes. These can include adaptation to climate change, livelihoods and taking preventive measures in preparation for the deleterious effects of climate change or climate shocks.

#### 5.1.1. Public policy frame

Consistency, continuity and coherence are ensured by a clear policy frame. In the context of minimizing the negative effects on farmers and marginalized communities due to climate change and the related shocks, the interest in safeguarding the most vulnerable must be enshrined in clear policy commitments. Failure to do so will divert attention and deflect government and public interest. If not addressed effectively, future impacts will have negative consequences of a larger magnitude. It is therefore necessary to identify a policy frame that will enable people's participation, promote good governance and investment in strategies and programs to minimize negative impact; such a framework must be agreed upon and adopted.

#### 5.1.2. Community cohesion

Farm families live in the context of village communities, which are characterized by a web of social relationships. These relationships are economic, social, and historical. Caste, class, socio-economic status, gender, and age are well-known dimensions along which communities are stratified. In the modern world, occupation, language, political affiliations and patronage, access to information and ICT, overseas capital flow due to migration, and social contacts, among others, add further dimensions to stratification. There are numerous ways in which communities are differentiated too. Differentiation by neighborhoods, institutional affiliations, occupations and membership in social groups such as professional and vocational associations makes communities complex. This complexity also provides a basis for cohesion and collective ethos. At a symbolic level, communities will have clear demarcation of territorial boundaries, names and other forms in which they develop identity. A cohesive community will be able to identify leaders, identify goals of collective interest, and steer these processes to achieve targets better than those that may be fractioned and in conflict. Communities that have different organizations addressing the needs of its members strengthen the people's sense of community and will be able to address the needs of the members more effectively. This is in the context of climate change and the deleterious effects that villagers may have to face, which is led by a well-informed cohesive community and well-meaning leaders who are able to address their needs more effectively than communities that are not cohesive and do not have an effective leadership structure.

#### 5.1.3. Local environment

The need to adapt to climate change is felt due to the realization that the extremes of weather changes experienced at present are the result of long-term climate change. National-level aggregated data analysis shows trends and changes. Some changes are significant while others may be more suggestive. There may be patterns emerging in terms of climate-related shocks that have catastrophic effects on people, property, and economies.

However, given the wide variability in agro-ecological situations within each country and also among the countries, the need for location specificity in interventions is imperative. The trends and mean analysis may mask and distort what is experienced at the local level. The local changes must therefore be analyzed and compared with the national aggregates when drawing inferences, conclusions and recommendations.

**Table 3**
Indicative policy points to strengthening the capacity to drought at the micro-level [a].

| |
|---|
| **Coordination**: An all-India climate change support program coordination body is established for effective coordination of all programs to avoid local level duplication and waste of efforts and resources |
| **Target relief support**: Ensure that relief is provided by the government through various programs and agencies and delivered at the village level to the appropriate target groups through a coordinating mechanism, established Panchayat, mandal and district levels, where the beneficiaries including women participate. Information of such programs is made available at the village level |
| **Villagers as active stakeholders in climate change information management**: All vulnerable villages should at least be integrated in a network of climate data collecting and management system for effective monitoring of local changes to target interventions where the villages act as active members of the climate change information management system of the country. The required training on climate/hydrological cycle, global warming, etc., for farmers to be provided |
| **Safeguard minimum thresholds of common property as a mitigatory measure**: Common property at the village level such as grazing lands, groundwater, community forests, etc., to be mapped and demarcated with appropriate participatory management strategies. Reallocation of common property is done only after safeguarding common interests |
| **Rational use of available water resources**: Regulate groundwater extraction through a system of licensing to ensure balance with natural replenishment rates |
| **Validate, upscale farmer adaptive strategies as socio-technological models**: The measures adopted by farmers to cope with the local situations of extreme weather conditions or climate changes to be cataloged, scientifically validated, tested for scalability and recommended for wider application. Learning from the grassroots to be made a key approach in adaptation research and development |
| **Reorient SAT farm strengthening programs:** SAT farm livelihood models to be developed considering the farmers as multi-enterprise entities that incorporate the service sector, labor markets, trading, etc. |
| **Credit support for income diversification**: Credit programs targeting the small and medium holdings in SAT villages to diversify farm enterprises to increase adaptive capacity to be provided. Such support programs to be supplemented with appropriate enterprise training and education for farmers as well as village level agro-climate extension and development workers |
| **Participatory governance**: The small and medium holders to be actively engaged in governance so that the local planning and distribution of relief and mitigatory interventions are done considering their needs and requirements; such collective engagements to be supported through local organizations (NGOs) |
| **Strengthen collective action**: Strengthen participation of villagers in collective action such as participating in local governance bodies to highlight climate change issues and promote SHGs as an adaptive measure |
| **Strengthen competence of professionals**: Mainstream climate change sensitivity to policy makers, government officials, development practitioners and scientists in various disciplines through ongoing training and development information disseminating programs |
| **Strengthen research:** Support research activities to be focused on (i) evaluating the effectiveness of adaptive strategies used by farmers, (ii) barriers to equitable distribution of relief programs to identify remedial measures, and (iii) local level climate or weather assessments to improve the quality of interventions |

[a] Recommendations from the ICRISAT coordinated project "Vulnerability to Climate Change: Adaptation strategies and layers or resilience" (Singh et al., 2012).

#### 5.1.4. Local governance

The ability of farmers to cope and adapt depends to a great extent on the governance system that prevails in the localities and the connectivity to the national governance system (Agrawal, 2008). The practice of good governance or best practices by all governance bodies will result in the best alternatives of livelihood provided to the people. An enabling environment for people to participate freely in governance ensures more positive outcomes such as reduction of poverty, famine, and economic development.

#### 5.1.5. Externalities

All villages and households are interconnected in a wide web of socio-economic relationships further enhanced today due to inroads in ICT that connect even the remotest human settlements. Thus with access to information, people can expand their worldview and live in different locations to escape risky, violent, and unsustainable environments. The extent to which the externalities are optimally used will be dependent on the availability and access to information relating to the external contexts and opportunities. This may be enhanced due to social contacts already available or through persons already in new locations or via information trickling from others who are aware of such opportunities (Jackson, 2005). Thus the above framework provides the direction and focus for investigation and analysis. Continuous crop or livestock failures, depletion of savings and assets, and non-availability of a local support system and state patronage to cushion against climate shocks will prompt many to leave their village and migrate.

## 6. Discussion and conclusion

Most of the regions in developing countries, particularly in the semi-arid tropics, are vulnerable to the current climate changes and climatic shocks in the future. Semi-arid areas are particularly vulnerable because limited opportunities for earning cash income lead to high levels of mobility and migration in search of better opportunities (Ryan and Spencer, 2001). Therefore, understanding the nature and degree of vulnerability is the initial concern of drought that helps to build strategies along the ground level context, to cope better with the climate extremes in the future. Among the different methods existing in analyzing impact is the Ricardian approach which is commonly used (Mendelsohn et al., 1994; Cline, 2007). Using farm value, which reflects long run profitability of the farm, or average net revenue in the case of unavailability of farm value data, one could estimate the values associated with climate variables and other variables that control non-climatic factors. One major advantage of this approach is that it captures long run impact of climate on farm price and also allows for farm level adaptation mechanisms. We can apply this approach in our study either by cross-sectional evidence or panel data approach. Another possibility is application of crop modeling which can help in understanding the yield responses to climate changes. But this approach ignores the linkages with the remainder of the economy, which would make the input prices and input allocations to agriculture endogenous. Minimizing the limitation of the crop modeling approach by using other methods such as computable general equilibrium models that describe inter-sector linkages can be an option. Also, changing models such as Agro-ecological zoning system (AEZ) models (Fischer et al., 2002) provide an innovative tool for understanding how climate change will impact agriculture in the future. The impact analysis using single or multiple approaches discussed in the previous part will entail linking between changes in climate events and changes in different aspects such as cropping pattern, income, employment status and gender issues of vulnerability with institutional and policy reforms over the years. This will empirically help understand, test and argue the links between climate change risk and changes in the socio-economic development status of a region as part of poverty reduction by looking into the impacts of climate change on these aspects. From the previous discussions we can view that there is no universal definition or conceptual approach to vulnerability which entails socio-economic and biophysical vulnerability to climate change. This study should be seen as complementing the integrated approach which entails both socio-economic and

environmental contexts of vulnerability. We will apply multiple approaches in addressing vulnerability. This provides a systematic investigation on the argument that degree of climate change vulnerability depends on socio-economic, political and environmental factors and the results will help in formulating alternative strategies and policies to address different dimensions of climate change vulnerability in an integrated way. Assessing climate change vulnerability in agriculture is essential in identifying the regions most exposed to its impacts and targeting such regions for building resilience against the impacts of climate change. To characterize regions based on vulnerability to climate change, a detailed vulnerability analysis was carried out in these target countries. A set of agro-socio-economic indicators was used to classify regions based on their extent of vulnerability. This analysis ascertains that all the semi-arid marginal regions of the South and Southeast Asian countries are highly vulnerable to climate change. Hence there are areas in a country where risks of climate change are high, whereas risks are low among others. In the future the new policies may appeal to eco-hydrological perspectives (e.g. Falkenmark and Rockström, 2004) in the arid and semi-arid regions. Focus on the conservation of natural resources, adopting integrated water resource management (IWRM) technological approaches and further streamlining in planning, allocating and managing water resources for irrigation, industry, and other purposes are needed.

## Acknowledgment

The study was conducted as a part of the multi-national project "Vulnerability to Climate Change: Adaptation strategies and Layers of Resilience" coordinated by the International Crops Research Institute for the Semi-arid Tropics (ICRISAT), Patancheru, Andhra Pradesh, India, with financial support from the Asian Development Bank (ADB).

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